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REVIEW OF

FRENCH LIMITED SITE

REMEDIAL INVESTIGATION REPORT

Prepared by

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Prepared for

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and

The French Limited Task Group

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INTRODUCTION

The French Limited Site, an abandoned waste pit on 15 acres south of State Highway 90 in Crosby, Texas, has been designated for Remedial Investigation/Feasibility Study (RI/FS) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) In December, 1982, the Texas Dept. of Water Resources, under a cooperative agreement with EPA, contracted to initiate a Remedial Investigation(RI) The field investigations were conducted and an initial RI report was completed by Lockwood, Andrews and Newman (LAN) in January, 1984. The French Limited Task Group was formed in late 1983 by potentially responsible parties to determine the most reasonable and environmentally acceptable remedial actions to be taken at the site. The Task Group contracted with Resource Engineering, Inc.(REI) to provide technical consulting services in support of the French Limited remedial investigations. A draft report documenting the additional site investigations developed by REI was issued by the Task Group in May, 1984 In April, 1985 upon EPA approval of a work plan, the French Limited Task Group entered into an Administrative Order to complete the RI investigations.

EPA generated extensive technical comments for both the draft and final RI reports submitted by the Task Group. The most critical and comprehensive issues raised by EPA involve the approaches and techniques for interpretation of geologic and hydrologic data. In order to resolve these issues ARCO Chemicals Company has authorized Applied Hydrology Associates, Inc (AHA) to prepare this independent review of the French Limited Site Final Remedial Investigation Report and associated EPA comments. The purpose of this review is to determine whether EPA has raised valid concerns about the analyses and interpretations made by REI in the RI report and to recommend alternative studies or interpretations that will help resolve EPA's concerns and facilitate evaluation of remedial action plans. The organization of this review follows Section III. EXPLANATORY COMMENTS from EPA's May 12, 1986 Comments on the April 1986, French Limited Remedial Investigation Report. This organization was selected because the EXPLANATORY COMMENTS provide EPA's major concerns with analyses and interpretation of geologic and hydrologic data.

REVIEW OF REMEDIAL INVESTIGATION REPORT AND ASSOCIATED EPA COMMENTS

1 0 Geology

EPA has questioned the interpretation of the contact between the Alluvium and the Beaumont based some of the boring logs (eg. GW-02 and B-11, Figure 11-1). Apparently, EPA believes that the red brown clay and underlying sandy silt identified in GW-02 and the red clay identified in B-11 are units in the Beaumont Formation. The boring log for GW-02 indicates that EPA's interpretation may be correct. The stiff red brown clay encountered at a depth of 36 ft below surface in GW-02 was identified as blocky in structure with slickensides -- a characteristic of the Beaumont. The red clay starting at a depth of 30 ft. below the surface in B-11 was identified in the boring log as a stiff red brown clay with silty sand lenses Perhaps this too is part of the Beaumont If the contact is modified to correspond with EPA's interpretation, it suggests a narrower river channel associated with the French Limited alluvium. It lends support to the interpretation of an erosional remnant (of the Beaumont) between the French Limited alluvium and the Riverdale alluvium Thus GW-02 may be completed in the Beaumont but it is by no means representative of the Beaumont. It is representative of a unit of the Beaumont that has been eroded from much of the site.

EPA has also questioned the existence of both the parallel alluvial channels and the "clay ridge" depicted on Figures 11-1 and 11-2. EPA has a valid point that the geologic information provided from borings is insufficient to conclude that there are parallel channels and a locally extensive "clay ridge" as depicted in Figure 11-2. An understanding of river hydraulics and alluvial deposition processes together with existing bore hole logs lends credence to the concept of an erosional remnant separating the French Limited alluvium from the Riverdale alluvium. Potentiometric data from shallow wells in the area also support the presence of a locally extensive zone with lower permeabilities separating the French Limited and Riverdale alluvial zones. The potentiometric map in the LAN report shows the steepening of the potentiometric surface in the vicinity of the clay ridge identified by REI. The higher gradient in this location is most logically explained by the occurrence of a zone of lower permeability.

Additional field work to support the alluvial geology interpretations in the RI may not be necessary. It would appear that EPA's questions may have been generated in response to the manner of presentation rather than limitations or deficiencies in the geologic information Although EPA fails to provide the basis for their concerns with the interpretations of the alluvial geology, it is likely that their primary concerns focus on the interpretations about the rate and direction of contaminant migration in the alluvial aquifer. In the RI report the geologic model is presented as a "fact" or starting point for the development of the potentiometric surface, flow directions and flow rates in the French Limited alluvium. As the geologic model is not fully supported by the existing geologic data, it is to be expected that EPA would question or attack the assumed model.

AHA recommends developing the potentiometric surface and contaminant concentration information for the alluvial aquifer and then interpreting how this information fits in with reasonable geologic models of the alluvium (see further discussion in Sections 2.1 and 3.1 of this report) If the primary issue is the rate and direction of contaminant migration, then the geologic model simply serves to explain or interpret the observed hydrologic data and contaminant concentration levels in the alluvium. Thus confirmation of the geologic model with additional drilling data is not necessary.

Finally, EPA has questioned continuity of the 15 ft. clay layer identified in the Beaumont (question 32). They argue that data from 4 borings and 11

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cone penetrometer tests cannot be extrapolated to a regional basis as implied in Section 5.3 of the RI. EPA insists that the RI address the possibility of downward movement of fluids and contaminants through interfingering of sands and silts in the Beaumont.

Since the geologic data represent only point samples in space, the continuity of the clay layer can never be "proven" by bore hole data alone. The existing bore hole and cone penetrometer data provide strong evidence for the occurrence of a continuous clay layer in the vicinity of the lagoon. Further drilling may not resolve this issue to EPA's satisfaction. The real issue is not whether there is a 15 foot thick continuous clay in the Beaumont beneath the site, but what is the natural magnitude of leakage from the alluvial aquifer through the Beaumont and the extent to which leakage could contaminate the deep aquifer.

It is in fact possible that a continuous clay, depending upon the extent of secondary permeability due to its structure, could have a higher rate of vertical leakage than a clay unit with interbedded sand and silt lenses Even though the laboratory tests of the clay unit in the Beaumont indicated extremely low permeabilities, it is not valid to apply permeability estimates from laboratory analysis of core samples to field conditions. The permeability of the clay layer is likely to be an order of magnitude or more higher than laboratory measurements. This occurs as a result of secondary permeability due to the structure of the formation or fractures that are not included in the laboratory tests or that are disturbed by sampling.

The issue of leakage through the Beaumont is crucial to the remedial action evaluation. Further discussion of this issue is included in Section 2 2 of this report. Recommendations for resolving this issue are included in Section 3.2.

2.0 Hydrogeology

2.1 Upper Ground Water Zone

AHA agrees with EPA that all valid surface and groundwater data in the unconfined aquifers should be used to construct a groundwater map. This information can then be explained or interpreted in light of a reasonable geologic model of the site. It is not surprising that EPA has not accepted the interpretation of an alluvial aquifer at the French Limited Site that is hydraulically isolated from the surface water bodies and surrounding unconfined aquifers without conclusive evidence to support such an interpretation (see previous discussion in Section 1 0). Geologic units and water bodies in contact with the alluvium would be expected to exhibit some degree of hydrologic communication. The magnitude of communication needs to be qualified rather than attempting to show hydrologic isolation of the alluvium. The analysis developed in Figure 11-2 should be presented as a simplified model of the dominant regional potentiometric gradient in the alluvial aquifer and not as a groundwater contour map. Recommendations for developing a groundwater contour map for the unconfined aquifers are provided in Section 3.1.

AHA's analysis of the information presented in the RI indicates that the proposed geologic model and estimated regional potentiometric gradient represent a reasonable interpretation. Nevertheless, the geologic units in the model should not be shown as hydraulically separated without the supporting data.

In order to estimate the rate and direction of contaminant migration in the alluvial aquifer, it may be beneficial to make some simplifying assumptions based on the geologic model. This is an accepted practice, provided that the estimates developed from the model are supported by observed data and the simplifying assumptions are not presented as facts (see Section 2.3 for further discussion). The analysis in the RI that led to the development of Figure 11-2 was an effort to assess the dominant rate and direction for groundwater movement in the French Limited alluvium based on simplifying assumptions and abstractions and should not be construed as a complete hydrologic representation of the upper aquifer at the site.

2.2 Pumping Test Analysis

2.2 1 Unconfined Well (REI 3-3) Test

A representative value for the transmissivity of the unconfined portion of the French Limited alluvial zone is important as it directly effects the calculated rate of contaminant movement in this zone. AHA agrees with EPA's comment that the steady-state Theim-Forchheimer analysis method employed in the RI is not the most appropriate method for evaluating the REI 3-3 test. The following reasons explain why the method is not appropriate:

1) The method is only valid for radial steady-state flow to the pumping well. Recharge effects from the adjacent sand pit invalidates the radial flow concept.

2) The apparent stabilization of water levels in the 3-3 observation well may be indicating the onset of "delayed yield" effects that would be expected in an unconfined situation. If this is the case then true equilibrium conditions required for the analysis technique are not in effect.

3) The water level fluctuation in the pumped well suggests that the pumping rate may have dropped slightly in the later parts of the test. Unfortunately, there is no record of pumping rate measurements or how a constant rate was maintained. Given the low pumping rate it is apparent that even minor fluctuations in the pumping rate in the order of 0.1 gpm will have a significant effect on water level response. The apparent stabilization in water level in the observation well may also be a response to a slight drop in pumping rate. Again, true equilibrium conditions for use of the steady-state method may not have been achieved.

The EPA comments on the use of the Theim-Forchheimer analysis dwell mainly on the validity of the method using data from the pumped well and one observation well. Their contention that two observation wells are required is not strictly true. While two observation wells render the method more reliable, the pumped well may be used as one of the observation wells provided that well-loss effects at the pumped well are not appreciable Given the low pumping rate during the test and relatively small drawdown in the pumped well it is likely that well-loss effects are minimal. The radius of the gravel-packed interval in the pumped well is generally used as the "r" factor in the form of the equation referenced by the EPA. The reference from "Ground Water and Wells" that states that the method is only valid if permeability is previously determined by other techniques is applicable if the equation is being used to predict well yield. In this case the well yield is known so that permeability may be calculated from the equation.

AHA recommends that the test be re-evaluated using a more appropriate non-steady state method. The short duration of the test will not allow a complete analysis of the unconfined characteristics of the zone as "delayed yield" effects may only have started to become apparent when the test was terminated. The early time data from the test may yield a reasonably valid estimate of the transmissivity of the zone but not an accurate estimate of the storage coefficient (specific yield). This is not a significant drawback, however, as representative values for the permeability and porosity of the zone are the major requirements for predicting groundwater flow rates. Porosity of the zone has been estimated from sieve analysis which is reasonably accurate. The specific yield of unconfined aquifers is usually similar to the average porosity value.

2.2.2 Aquifer Recharge

The drawdown and recovery data from a pumped well must be interpreted with caution due to a number of factors which cause deviations from the idealized conditions assumed in the formulation of analytical methods. One of the often overlooked factors which may influence pumped well data is well-bore storage. Well-bore storage effects have been documented to have significant influence on early time drawdown and recovery data in pumped wells, particularly in low permeability formations when low pumping rates are used (Schafer, 1978). A copy of this paper is included with this report.

The rate of drawdown and recovery in pumped well during periods influenced by well-bore storage are much higher than under the assumptions of the standard non-steady state analytical techniques used in the RI and by EPA Well-bore storage effects cause a relatively steeper slope in the early-time drawdown and recovery semi-log plots. Use of the early-time data thus leads to underestimations of transmissivity values and possible misinterpretation of the later, flatter slope on the semi-log plot as being caused by recharge or leakage effects. Observation well data may also be influenced by well-bore storage effects but generally these effects are minimal in comparison with the pumped well. Consequently, a well test conducted with an observation well is required to adequately assess the hydrologic characteristics of the deep aquifer.

Examination of the well specifications and pumping rate used in the 3-4 well test using a method proposed by Schafer (1978) indicates that well-bore storage effects would be apparent in the pumped well during the initial 60 minutes of both the drawdown and recovery periods of the test.

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EPA's suggestion of "recharge" to the deep aquifer during the 3-4 well test is based primarily on the observation of a significant decrease in the rate of drawdown after about 60 minutes of pumping and the fact that extrapolation of early-time recovery data indicates a return to equilibrium conditions significantly earlier than would be expected under non-recharge conditions. Both analyses use data from the early portions of the drawdown and recovery periods which are influenced by well-bore storage. Drawdown and recovery data during these periods should not be included in the analysis. The aquifer characteristics should be calculated using data collected after well-bore storage effects become negligible, represented by the later, flatter portion of the semi-log plot.

The drawdown data during the period following significant well-bore storage effects is rather erratic and it is not possible to determine aquifer characteristics or make any conclusive interpretations regarding possible "recharge" effects. Examination of the recovery plot presented by EPA indicates that the latter time data does show the expected flattening although recovery measurements were terminated a little too early for an accurate analysis of this portion of the test. It would appear that extrapolation of the later recovery data which is not influenced by well-bore storage may not indicate significant "recharge" effects.

The well-bore storage influence on pumped well data during the early-time portions of the test obscures the observation of recharge, leakage or boundary conditions that may have been encountered during this period. However, the potential of leakage from the French Limited alluvium during the test cannot be eliminated on the basis of the available data. Contamination of the deep aquifer indicates that communication exists, or has existed during the past 20 years, and artificial penetration of the overlying aquitard has been suggested as a possible cause. Consequently, leakage from the alluvium via artificial penetrations is conceivable.

In summary, the REI 3-4 well test was not designed in a manner that could adequately characterize the deep aquifer and quantify the effective hydrologic communication between the deep aquifer and the French Limited alluvial zones. Recommendations on how this may be accomplished during additional tests are given in section 3.2.

The analysis of drawdown and recovery data from future well testing may indicate the influence of "recharge" conditions. However, the use of the term "recharge" is misleading. Recharge in the context of pump test analysis refers to any process which results in a net increase in the amount of water available to the pumping well over that which would be derived from an ideal aquifer having the same characteristics as encountered in the early portions of the test. Consequently, "recharge" may actually be derived from the pumped aquifer itself if the hydrogeologic characteristics of the unit are not uniform. Given the relatively complex geology at the French Limited site it should be expected that drawdown responses may not follow the theoretical drawdowns predicted by analytical techniques that are based on fairly ideal conditions.

Recharge effects that may be indicated by drawdown and recovery data of future well tests in the deep aquifer may be explained by a number of causes and a thorough examination of the geologic framework is required to

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make the best interpretation as to which cause is most likely. There is considerable evidence to suggest that the deep aquifer is relatively isolated hydrologically from the overlying French Limited alluvial deposits at this location, primarily the 80 foot head difference between the two units. Leakage from the overlying aquifer is not the most likely source of recharge effects. Some of the other more likely explanations of recharge effects are as follows:

1) A higher transmissivity in the deep aquifer at a distance from the pumped well. This may be a result of a thickening of the unit or a higher average permeability due to variation in clay content or overall grainsize within the unit

2) Delayed yield of water stored in clayey zones within the pumped unit or from the overlying and underlying aquitards.

3) Stratification of the pumped aquifer with cross-flow from lower permeability units to higher permeability units as a head differential is developed between these units.

4) Leakage from underlying aquifers

All these processes are consistent with the geologic conditions at the site and should be considered in the design and analysis of future well tests in the deep aquifer. The recommended testing program presented in section 3 2 attempts to avoide these issues by directly measuring the response in the aquitard and overlying alluvium that occurs as a result of stress testing the deep aquifer.

The issue of sufficient aquifer stress has been raised by EPA. The 30% drawdown achieved during the REI 3-4 well test appears to be reasonable. Sufficient aquifer stress for the test also concerns the time over which the stress is imposed. AHA's preliminary calculations indicate that a 24 hour test is not sufficiently long to adequately determine the degree of communication between the deep aquifer and the overlying alluvium Recommendations in Section 3 2 address the design of a test that should determine the degree of communication between the two aquifers.

Water level fluctuations in the alluvial monitoring wells during the test have been explained by barometric effects. This statement should be supported by barometric readings if possible in light of EPA's concerns regarding possible communication. If barometric pressure fluctuations during the test were not measured then the water level fluctuations may be construed as evidence of communication with the deep aquifer.

2.3 Groundwater Flow Rates

AHA disagrees with EPA's contention that accurate estimates of groundwater flow rates are of primary importance to the identification of contaminant distribution in the groundwater regime The identification of the contaminant distribution should be based on accurate sampling and analysis of contaminants in the groundwater system. Accurate estimates of groundwater flow rates and directions may be beneficial to explain the source of observed contamination or to predict future contamination.

EPA appears to be placing too much emphasis on accurate estimates of groundwater flow rates and direction. An accurate model of groundwater flow rates, velocities and direction of movement would require additional information on permeabilities, boundary conditions and recharge rates. The transient effects of flooding and recharge or discharge to and from the surface water bodies would be extremely difficult to identify and incorporate into a model of the hydraulics of the unconfined aquifer Estimates derived from a steady state analysis using data at a particular point in time will depend on the transient recharge and discharge conditions at that time and may not reflect the dominant direction and rate of transport.

The analysis presented in Sections 11.5 and 11.6 of the RI was an effort to remove the effects of local recharge and discharge and to eliminate the complexities due to variable transmisivities for different geologic units in order to construct a dominant direction and rate of contaminant migration in the unconfined aquifer. This analysis was supported by observations of contaminant levels in the aquifer.

It seems likely that the transient effects of recharge and discharge and flooding would increase the dispersion of contaminants in the unconfined aquifer. For instance, flooding effects could result in low levels of contamination at locations not anticipated from groundwater analysis. Furthermore, this dispersion zone could overlap with the dispersion zones from other contaminant sources in the area.

Given that remedial action will be taken to prevent the continued migration of contaminants from the site, it would appear to be unproductive to dwell on accurately quantifying the rate, direction and velocity of groundwater movement in the unconfined aquifer. The approach taken in the RI is a reasonable effort to estimate the dominant rate and direction for contaminant migration although it may be necessary to update the analysis using regional gradients developed from the re-analysis of the potentiometric surface and using revised estimates for alluvial aquifer porosities and permeabilities (see Section 3.1 for recommendations concerning re-analysis of the hydrogeology of the upper groundwater zone). AHA concurs with EPA's comment that the basis for the porosity values used in the groundwater velocity calculations be documented. The estimate of 30%, derived from sieve analysis of zone 3-3 of the unconfined aquifer as presented in Table 6.7 of the RI may be the most appropriate estimate of porosity for the unconfined aquifer.

EPA requests that the Task Group consider the potential distribution of contaminants in the deep aquifer (Zone 3-4) based on a valid interpretation of pumping tests results. There is no basis to support EPA's suggestion that the recharge effects were observed in the deep well pump test as explained in detail in section 2.2. AHA agrees that the contamination observed in the deep aquifer ought to be explained by more conclusive evidence. We feel that the results of the additional studies suggested in Section 3.2 of this report should provide this type of data.

Further characterization of the deep aquifer is necessary to assess the feasibility of an on site closure. This information would be used to assess the impact of anticipated leakage through the Beaumont formation.

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Contaminants would not be detected in the deep aquifer if the rate of leakage is sufficiently small relative to the rate of flow and dispersion in the deep aquifer. This evaluation would require information on anticipated leakage rates developed from the recommended studies in Section 3.2 and estimates of flow rates and approximate dispersion coefficients for the deep aquifer. Since, this assessment is likely to be completed under Feasibility Studies, detailed recommendations are not provided in this report.

3.0 Recommendations

3.1 Hydrogeology and Contaminant Migration in the Upper Groundwater Zone

The following recommendations were developed based on AHA's determination that EPA's concerns with the hydrogeologic analysis of the upper aquifer stems from the presentation of the analysis rather than from significant deficiencies in the data.

1) Further geologic analysis appears to be unwarrented. Complete determination of the geology of the site is not necessary for interpretation of the rate and direction of contaminant migration. A satisfactory interpretation of the rate and direction of contaminant migration in the upper aquifer has been developed in the RI. This analysis should be updated as described in Section 3.1.4 based on the results of the refinements in the hydrologic information as described below.

2) A groundwater contour map of the upper aquifer should be developed using information from all wells in the upper aquifer as well as water levels from surface water bodies in the area. This analysis will resolve many of the questions raised by EPA. Interpolation of groundwater contours can be developed with a basic understanding of the mechanics of groundwater flow in unconfined aquifers using the known water levels, the topography of the area and the geologic model of the upper aquifer. The geologic model is used to interpret the hydrologic data and the hydrologic data helps support the geologic model.

   Water levels collected on the same date or reasonably close to the same date should be used The map should show the actual water levels at measured locations and the measurement date as well as the interpolated groundwater contours. If possible a separate analysis should be performed for a wet period and a dry period in order to provide a better feel for the transient effects associated with recharge and discharge in the area. The analysis should incorporate data from monitoring wells in the unconfined aquifer at the Sikes site. This information would allow a more accurate and defendable interpretation of the regional gradient controlling groundwater movement at the French Limited site. This information is needed for the revised assessment of the direction and rate of contaminant transport in the upper aquifer as described in item 4 below.

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3) Pump test results from the upper aquifer recommended in Section 3.2 should be used with results from the REI 3-1, 3-2 and 3-3 tests and the slug tests to characterize the expected transmisivity of the alluvial aquifer and the likely range in this estimate. Porosity estimates should be developed based on sieve analysis of drill samples and comparison with literature values for similar aquifer materials. An expected porosity value for the upper aquifer should be developed along with a likely range for this estimate. This information can then be used to complete the revised contaminant transport analysis described in Section 3.1.4

4) A revised assessment of the rate and direction of groundwater transport should be developed following completion of the previous steps. If mounding or sinks associated with the surface water bodies are local, the effect of these features can be removed from the regional contour The analysis should show zones where significant changes in transmisivity can be expected to occur. A regional gradient can be developed from the regional groundwater contour map to assess the dominant direction and rate of groundwater flow in the upper aquifer. The analysis should be performed using the upper and lower range of transmisivity estimates as well as the expected value. Velocity estimates can be determined from the flow estimate and an estimate of porosity of the aquifer. Again the range for these estimates as well as the expected value should be used to determine a range and expected value for groundwater velocity

   It is important to recognize that groundwater velocity represents the expected rate of movement of a conservative(non-reacting) contaminant. Actual rates of contaminant transport may be reduced as a result of retardation by adsorption or chemical reactions. Furthermore, the velocity estimate represents an average for the aquifer. Individual molecules of water or contaminants will move faster and slower than the average. Thus, it is possible for contaminants to appear at low concentrations beyond the range predicted by the velocity calculation. These effects are referred to as mechanical dispersion.

3.2 Leakage through the Beaumont Formation

The quantification of the effective communication between the French Limited alluvium and the deep aquifer is critical to the evaluation of remedial action plans for the site. The geologic and hydrologic data collected at the site strongly support the existence of a continuous clay layer in the Beaumont Formation that probably has the characteristics to effectively isolate the two units. However, the existence of significant contamination in the deep aquifer indicates that communication with the overlying alluvium exists, or has existed during the past 20 years. The nature of this communication is not conclusively proven and the EPA has raised questions about the interpretation given in the RI report.

Three possibilities have been identified to explain the presence of contamination in the deep aquifer·

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1) Communication through artificial penetrations in the clay layer particularly near well GW-25. This is the interpretation given by the Task Force and the evidence given in support of this includes:

   o The relatively discrete incidence of contamination in the deep aquifer

   o The suggestion of a groundwater "mound" in the vicinity of the GW-25 well

   o Drill hole data that indicate continuity of the clay layer

   o A head difference of about 80 feet between the alluvium and the deep aquifer that indicates very poor natural hydrologic communication

   o Extremely low laboratory permeability values of the clay.

2) Discontinuities, such as sand lenses, within the clay layer that would allow significant communication between the two aquifer units in relatively discrete areas. This has been suggested by the EPA with no supporting data. The head difference between the two aquifer units and the drill hole data do not support this interpretation. However, the possibility is difficult to disprove completely on the basis of these data.

3) Natural leakage through the continuous clay layer under the high vertical hydraulic gradients. This possibility has also been suggested by the EPA and would require that the natural vertical permeability of the clay layer several orders of magnitude higher than laboratory measurements indicate. Given that the clay is stiff and slickensided, higher field permeabilities for the clay layer are reasonably likely. The major argument against this possibility is that contamination was not found in the clay layer at three drill hole locations within the lagoon area. Again, the data cannot disprove the possibility completely as it is taken at discrete points.

While the existing data do indicate that artificial penetration is the most likely cause of the deep aquifer contamination, the proper evaluation of remedial action alternatives necessitates that the communication between the deep aquifer and the alluvium be determined more quantitatively. The emphesis of the recommended test program described below is to achieve this objective.

AHA recommends that a hydrologic test program be conducted in the vicinity of the GW-25 well that is specifically designed to identify the cause and quantify the degree of vertical communication between the deep aquifer and the alluvium. In addition, data from the tests will be used to better define the hydrologic characteristics of the deep aquifer, the shallow aquifer and the Beaumont aquitard at this site. This data will be used to assess the impacts of anticipated leakage of contaminants from the overlying alluvium. This location is recommended for the testing program because of the contamination in the deep aquifer which has been identified from samples taken from the GW-25 well. This infers that significant hydrologic communication with the alluvium may exist at this site and may be quantified by testing.

The recommended testing program consists primarily of conducting a relatively long-term well test in the deep aquifer and monitoring responses in the overlying clay layer and French Limited alluvium. Additional recommended testing at the site includes at least one and preferably two short-term tests in the lower unit of the alluvium and single-well response tests in the clay layer.

The recommended well layout to perform the program is shown in Figure 1 attached. The layout requires an additional deep aquifer well, three shallow wells completed in the lower part of the French Limited alluvium and two piezometers completed in the lower and central parts of the clay layer.

The new deep aquifer well will be utilized as the pumped well for the deep aquifer test. The well should be completed in a similar fashion to the 3-4 well and located about 15 feet from the GW-25 well. The existing GW-25 well will be used as a monitoring well for the deep aquifer test to allow a more definitive determination of deep aquifer characteristics than was possible at the 3-4 site.

The alluvial wells should be completed with 4 inch diameter casing in a similar fashion as the REI 3-3 well. The location of the alluvial wells in a triangular pattern at varying distances from the GW-25 well as shown in Figure 1 is designed to evaluate the contention that the well may be a conduit for contaminant migration to the deep aquifer. Static water level elevations in the three wells may reveal a hydraulic gradient towards the GW-25 well if significant leakage is taking place at this location. This process may also be revealed by the relative response of the three wells (if any) during the deep aquifer test. If the three wells show responses during the deep well test that are essentially the same then this would be indicative of a more uniform communication across the clay layer. During the deep aquifer test, it is recommended that packers should be set on one inch diameter pipe above the screened intervals of the alluvial wells so that water level responses will be more sensitive.

The clay piezometers should be completed using 1-2inch ID pipe through surface casing using similar techniques as recommended for the deep aquifer well. The lower sections of the piezometer holes should preferably be drilled using auger or air-rotary techniques. Screened and sand-packed intervals for the piezometers should be about 2 feet in length

Initial calculations assuming various values for the hydrologic properties of the aquifers and the clay layer indicates that the deep aquifer test should be conducted for about six days. It is recognized that the available drawdown and limited permeability in the deep aquifer may not make this practical. The test should therefore be conducted as long as feasible. The alluvial wells and clay piezometers will be monitored during the deep aquifer test. Placing stress on the lower aquifer for several days should allow responses to be seen in the clay layer piezometers and possibly the overlying alluvial wells. It will be necessary to also

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monitor barometric pressure to evaluate possible barometric effects during the test.

As indicated above, it is recommended that a short-term (1-2 day) pump test be conducted on at least one of the shallow wells using the other two wells for observation. These tests will allow a more definitive determination of the alluvial hydrologic characteristics at this site. These values are necessary for complete evaluation of the deep well test results, particularly if responses are observed in the alluvial aquifer. In addition the test results will indicate whether the values derived from the tests at REI site 3 are representative of the area.

The two piezometers installed in the lower and central sections of the clay layer will serve a number of functions. Single-well response tests may be conducted on the piezometers to obtain direct information on the permeability of the clay unit. Comparison of field permeability values calculated from these tests with laboratory permeability measurements will indicate whether secondary features such as fractures or slickensides are significant with respect to the retardation characteristics of the clay layer.

The single-well response tests yield data on the lateral permeability of the unit rather than the vertical permeability. Monitoring of the piezometers during the deep well test will allow quantitative assessment of the vertical permeability of the clay layer. If communication exists between the two aquifers via the GW-25 well casing annulus or sand lenses then responses in the clay layer will be minimal and will probably be less than responses in the overlying alluvial monitoring wells Significant leakage from the clay layer would be indicated by responses in the lower clay piezometer and possibly the central clay piezometer An estimate of the vertical permeability in the clay layer may be made using the piezometer response data and accepted analytical techniques. It must be noted that the anticipated low permeability may result in a very slow recovery of water levels in the piezometers following completion and response testing. Allowance should be made for a sufficient recovery period so that equilibrium conditions occur prior to the deep aquifer test The recovery period could be as long as several weeks and should be monitored by periodic level measurements.

Water quality samples taken from the piezometers may also yield direct evidence of any movement of contaminants through the clay layer as opposed to movement via artificial penetrations or sand lenses in the vicinity of the GW-25 location. Of course, extreme care must be taken during the installation of the deep well and the clay piezometers to insure that contamination does not occur as a result of drilling and well completion Casing should be set and grouted through the upper aquifer and into the Beaumont clay unit. After the casing is set and before drilling into or through the clay, the drill stem should be decontaminated. Bentonite should be placed above the piezometers to insure that leakage does not occur down the annular space.

It is believed that the recommended testing program should resolve many of the conflicting interpretations that have been suggested regarding the nature and extent of communication between the deep aquifer and the

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overlying alluvium. If this can be effectively done then the feasibility of remedial actions for the site such as on site closure may be properly evaluated.

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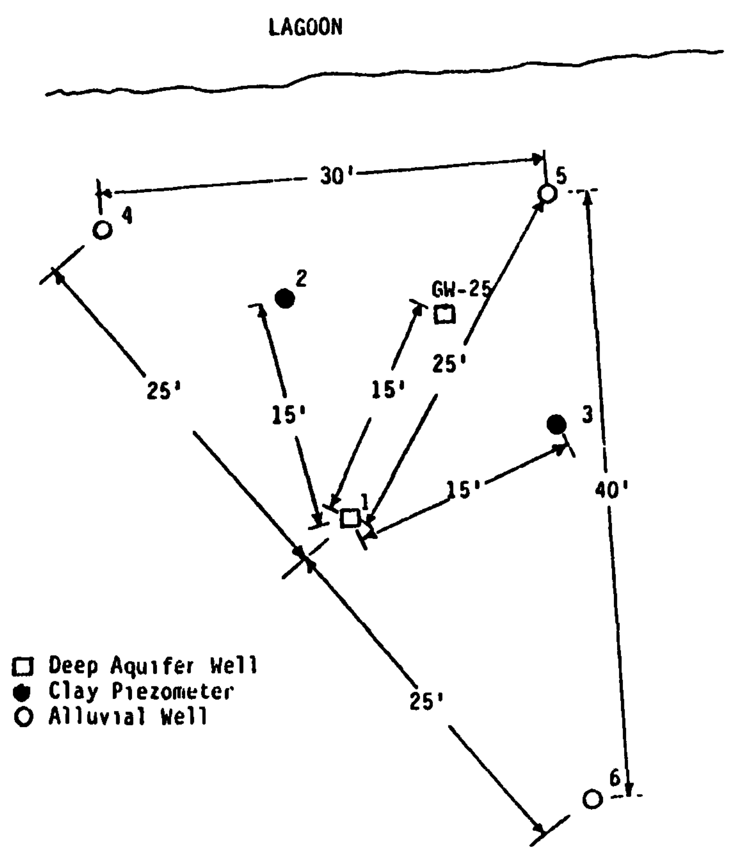
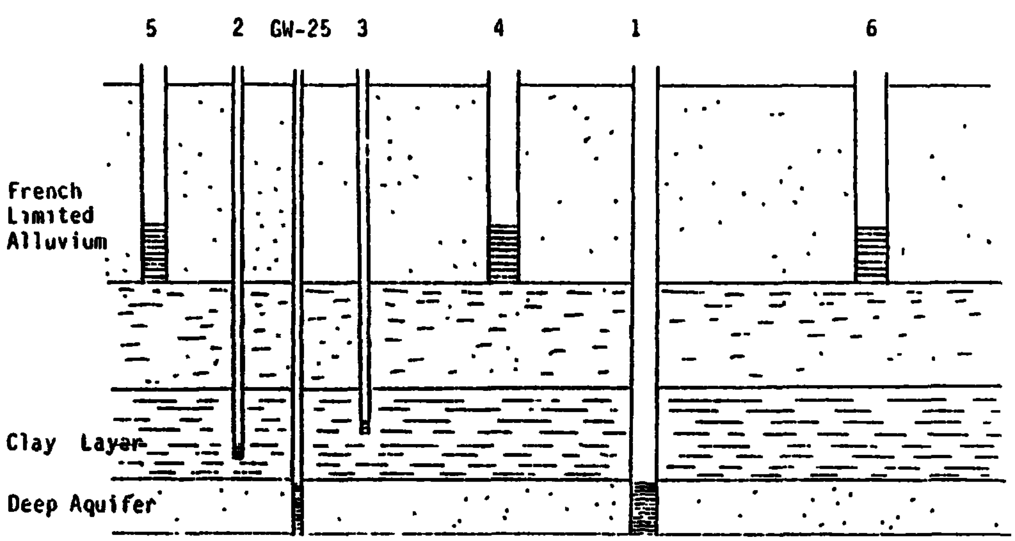
Figure 1 - Proposed Well Configuration for Testing Program



a) Plan View



b) Cross-sectional View